Ionospheric convection modeling based on convolution with a localized vector-valued basis function

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Divergence free assumption is useful for modeling the flow velocity distribution in the ionosphere where plasma velocity can be assumed to be orthogonal to a potential electric field. If the divergence of two-dimensional plasma velocity is assumed to be zero, we can consider a stream function yielding the plasma velocity distribution. In order to estimate the two-dimensional flow velocity distribution in the ionosphere, we propose a framework which expresses the stream function by a convolution with a spherical Gaussian function. From this spherical Gaussian function, we can obtain a localized vector-valued basis function for flow velocity distribution satisfying the divergence-free condition. Accordingly, flow velocity distribution can be represented by a convolution with the vector-valued basis functions. We combine this model with a state space model and estimate a temporal evolution using the Kalman filter algorithm. Hyperparameters of the model are determined by maximizing marginal likelihood.

The proposed framework is applied for estimating the two-dimensional ionospheric convection pattern from the Super Dual Auroral Radar Network (SuperDARN) data. Although there are some wide gaps in the spatial coverage of the SuperDARN radar network for ionospheric observation, the use of the localized basis function enhances the robustness of the estimate. This basis function also enables us to evaluate the uncertainty of the estimate which would be helpful for incorporating other observations. Some results of the analysis of the SuperDARN data will be demonstrated.

Keywords: ionospheric convection, SuperDARN, spherical Gaussian function